Photoemission Electron Microscopy and X-Ray Magnetic Circular Dichroism of $Fe_xNi_{(1-x)}$ Thin Films on Cu(111)

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INTRODUCTION

Our research focuses on controlling the structure, composition and the resultant magnetic properties of metal alloy thin film growth at the atomic level. Better understanding and control of surface/interface magnetism is relevant to the application of the giant magneto-resistive effect to read heads for magnetic recording. We have studied $Fe_xNi_{(1-x)}$ alloy thin films for their technological relevance to the above mentioned technology. The dependence of the magnetism on the stoichiometry x is one of the questions of interest. In addressing this problem, the structure of the thin film must be also considered. In terms of crystal structure, a well known "Invar effect" exists in bulk FeNi alloy because of structural incompatibilities of the two elements. Pure Fe is stable in bcc phase whereas pure Ni has fcc structure. A bulk alloy containing more than 65% Fe transforms to bcc by a Martensitic transformation, and the magnetization falls to zero. In thin film alloys, the problem may become more complex because of the effect of substrate structure and interface properties. On the other hand, how this structural change affects the magnetic order in the film is not well known. A simultaneous study of film structure, magnetic structure and magnetism is needed to better understand the system.

Several studies on $Fe_xNi_{(1-x)}$ alloy thin films have been reported[1,2,3,4]. Information on the growth, structure, and magnetic moments as a function of thickness and concentration has been obtained using various techniques such as low energy electron diffraction (LEED), reflection high energy electron diffraction (RHEED), photoelectron diffraction, surface magneto optical Kerr effect (SMOKE), X-ray magnetic linear dichroism (XMLD), Mossbauer spectroscopy, and superconducting quantum interference device (SQUID) magnetometry. We have used the photoemission electron microscope (PEEM2) at the Advanced Light Source (beamline 7.3.1.1) to study this film system. PEEM has the unique capability of imaging the film's magnetic structure with high spatial resolution and elemental specificity. Simultaneously, quantitative magnetic information can be obtained using magnetic circular dichroism in X-ray absorption spectroscopy. At two different thicknesses, we have studied the dependence of magnetic structure/magnetism on varying Fe concentration (x = 0, 0.28, 0.55,0.6, 0.66, 0.74, 1.0 at ~10Å≅5ML, x = 0.33, 0.42, 0.55, 1.0 at ~20Å ≅10ML). We have observed clear ferromagnetic domain structures of the film on a Cu(111) surface for $x \leq 0.60$ at room temperature. Quantitative analysis of magnetization in the film is in progress.

RESULTS

Samples with high Fe content (x=0.66, 0.74 at 5ML) have been observed to be non-magnetic at room temperature. All other alloy samples ($x \leq 0.6$, 5ML and 10ML) showed clear ferromagnetic contrast. This trend of reduction in Curie temperature at higher Fe concentration is also observed

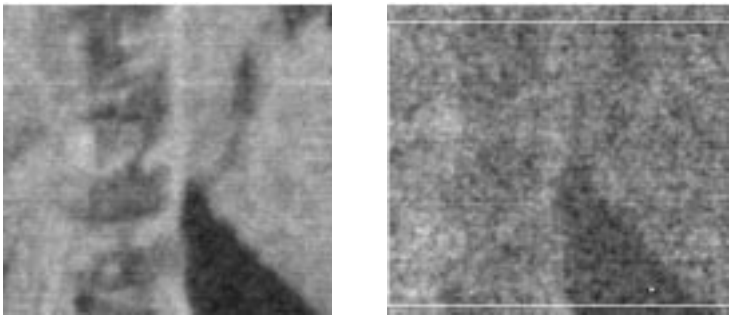

Fig.1. XMCD ferromagnetic images with a 12μ m field of view for a 5ML thick $Fe_{0.6}Ni_{0.4}$/Cu(111).
Left: Fe XMCD contrast, Right: Ni XMCD contrast

by spin resolved photoemission spectroscopy measurements carried out at the Advanced Light Source (beamline 7.0.1.2). A pure Ni film at 5ML thickness was non-magnetic at room temperature. According to a SMOKE measurement, 5ML is approximately the thickness where the Curie temperature becomes less than room temperature for Ni/Cu(111)[5].

Fig. 1 shows typical ferromagnetic images with a 12μ m field of view for a 5ML thick $Fe_{0.6}Ni_{0.4}$ film on Cu(111). Each image is obtained by dividing an image acquired at the L3 Fe (or Ni) edge by one acquired at the L2 Fe (or Ni) edge. The images show alignment of the magnetic domains for Fe and Ni, suggesting that Fe and Ni form a good alloy on this surface. Comparison of the image at the pre-absorption edge, which shows only topographic contrast, with the magnetic contrast image clearly shows the correlation between surface structural features and the formation of magnetic domains. When domain sizes are compared for different Fe concentration, elongated larger domains (~10μm) are observed for higher Fe content (x=0.42, 0.55, 0.6). On the other hand, at lower Fe content (x=0.25, 0.33), typical domain sizes were on the order of 2 to 5μm.

Magnetic contrast observed at room temperature disappears gradually upon heating. Contrast is recovered again as the sample temperature is lowered below the Curie temperature. This also confirms the relation between domain structure and surface geometric structures. These observations are consistent with each sample analyzed.

Magnetization in each sample can be quantified by comparing the dichroism from the spectra obtained in different regions of the sample. Fig 2 shows magnetic domains on the above sample with the corresponding spectra measured in those domains. Quantitative analysis of magnetism in the film as a function of Fe content and film thickness is in progress.

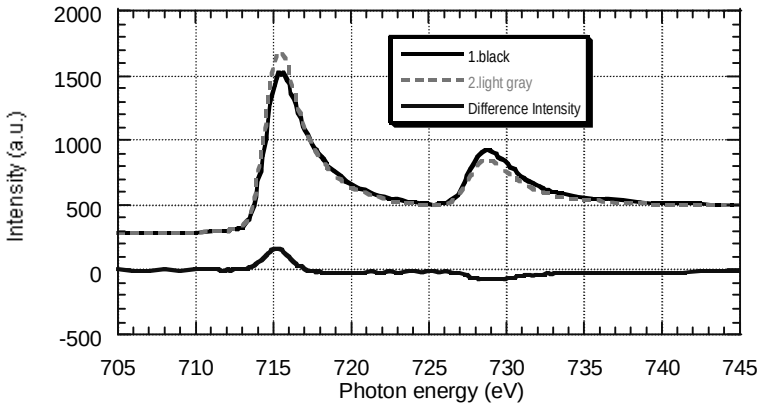

Fig.2.(a) Magnetic dichroism of Fe L3 and L2 edges from two different regions (labeled 1 and 2) in Fig.2.(b).

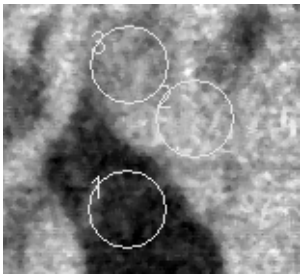

Fig.2.(b) XMCD ferromagnetic image with a 10μ m field of view for a 5ML thick $Fe_{0.6}Ni_{0.4}$/Cu(111)

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